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Documentation of BRUSII used on Egyptian data

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Risø National Laboratory, Roskilde
1995

Abstract

The BRUSII model and its use on Egyptian data are documented in this report. A Master Plan for wind development in Egypt is a part of the project, Demonstration and Development of Technology and Planning in the Wind Energy Sector in Egypt. The Master Plan work is has been carried out in cooperation between New and Renewable Energy Authority (NREA) in Cairo and The System Analysis Department of Risø.

In the work the BRUSII model has been used to analyze the perspectives for wind development in a fully specified energy system. BRUSII has its origin in the BRUS model developed and used in connection to the Danish energy plan 2000. The model has been adapted to suit Egyptian conditions, but elements originating from the Danish energy system are still present. Thus the model could be used to examine a system including a demand for heating.

All 20 spreadsheets of the model are documented, regarding their main input data, calculations and output and to some degree the assumptions made.

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Preface

A Master Plan for wind development in Egypt is a part of the project, Demonstration and Development of Technology and Planning in the Wind Energy Sector in Egypt. The Master Plan work is has been carried out in cooperation between New and Renewable Energy Authority (NREA) in Cairo and The System Analysis Department of Risø.

In the work the BRUSII model has been used to analyze the perspectives for wind development in a fully specified energy system. BRUSII has its origin in the BRUS model developed and used in connection to the Danish energy plan 2000. The model has been adapted to suit Egyptian conditions, but elements originating from the Danish energy system are still present. Thus the model could be used to examine a system including a demand for heating.

In the Master Plan work the model has been used to demonstrate possible developments for wind and other renewables as a production capacity of electricity in Egypt. The scenarios that have been carried out are used in illustrating long term perspectives of wind, and is not used in the actual planning of wind expansion. The years 2010 and 2030 was chosen in the first scenario analysis carried out on Egyptian data.

To plan for wind energy development there is a need to investigate total electricity supply and demand relations. Using the model implies collecting a huge amount of data, which is not a simple case in Egypt. Scenarios have been based on available data and specially some of the detailed demand categories have a lack of accurate data. Most emphasis has been given to the data and handling of energy supply.

Introduction to BRUSII

BRUSII can be characterized as a bottom-up model of the energy system. Both demand for energy and supply of electricity is described in detail. The structure of the model is a detailed bottom-up description of energy demand and technologies in the use of energy. Supply of converted energy is only a part of the model. Electricity supply is described as produced from traditional thermal plants, renewables including wind, hydro and solar. There is special emphasis on the wind supply as well as future technologies. Basically BRUS is a scenario projection for a medium term year and a long term year.

BRUSII is organized as a spreadsheet model using Quattro Pro but it is quite easy to convert to e.g. EXCEL. The systems consist of 20 sheets documented in short below of which some are primarily input sheets and a few sheets are primarily output sheets. As a bottom-up model, demand for energy is determined in separate sheets for different demand categories. The demand categories are

- Household demand for heating and hot water. (Fen-house)
- Household demand for electricity for electric appliances. (El-appl)
- Demand for electricity in service sector. (En-service)
- Industrial demand for energy in process. (En-proc)
- Transport energy demand. (Fen-tran)

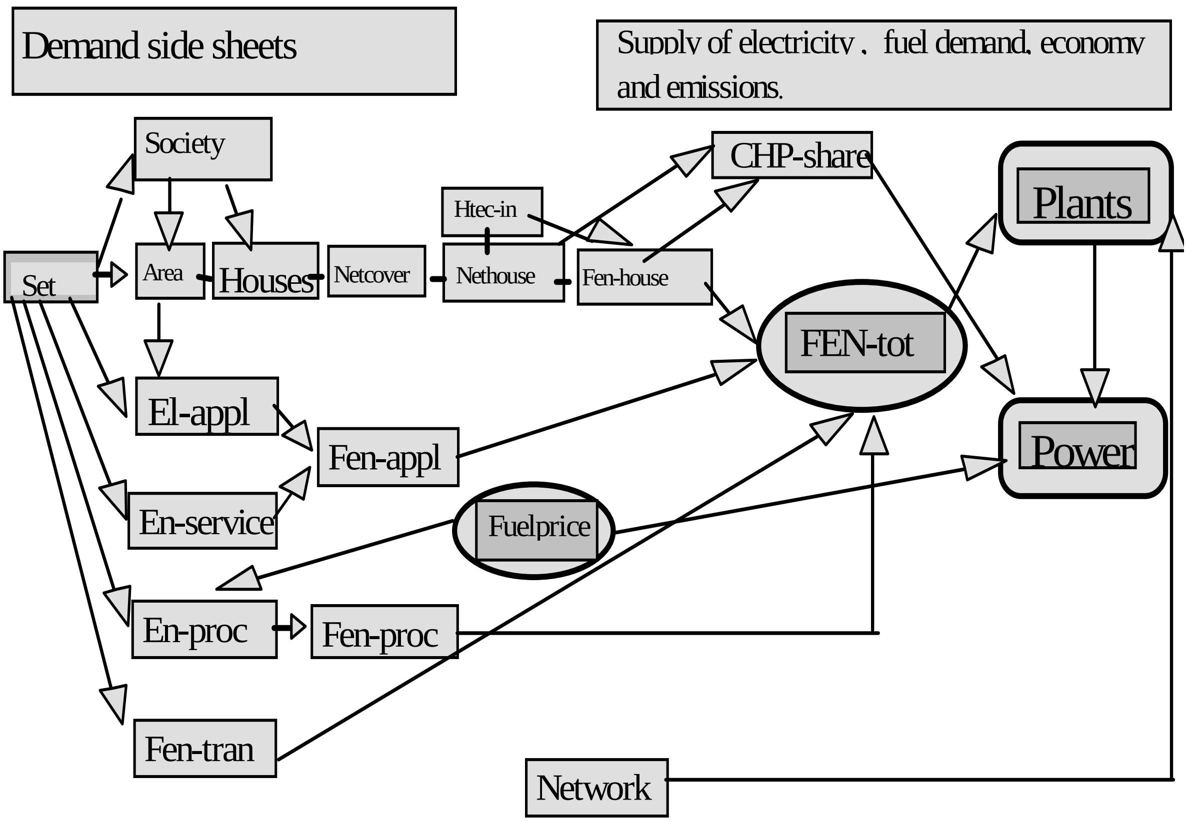
Each of these demand categories are determined independently and by different basis assumptions. Household demand is a result of projections on population, new dwellings and specific saturation degrees for appliances. Service sector energy demand is primarily exogenous which is also the case for transport energy demand. Industrial demand is determined both by production and fuel prices including both types of elasticities.

All demand categories are added in the Fen-tot sheet, which constitutes the input to the Plants and Power sheets in respect to electricity demand. Electricity is produced by a number of plants, which are specified regarding capacity, fuel type and fuel efficiency.

The model could be used by setting up a number of scenarios including both demand side and supply side options. It is possible to use the model only from the demand side or from the supply side taking electricity demand as given.

The main output from scenarios is total energy demand, which forms the basis for calculations on electricity production, with information about resulting fuel demand, production cost and emissions. A relevant use is the comparison of electricity demand and the planned development of electricity producing capacity. This is one of the features that have been used in the work in Egypt as it gives the opportunity to investigate reasonable expansion plans for wind capacity.

BRUS-II



SET: Input sheet

Sheet setting up different years, base year, midterm projection and endyear projection. Concerning housing areas related to cooling demand etc. one setting on parting old buildings from new was set to 1980. The settings on the years work throughout the model.

SOCIETY: Input sheet

Economical and demographic data is set here of which population development is the most important factor determining energy demand development specially on cooling and hot water as well as housing appliances.
Input: population 92 and projections for the years 2010 and 2030.
GDP 92 and real growth rates in the two periods until 2010 and from 2010 till 2030. GDP is not used directly in the other sheets but serves as an indication, when predicting output development in producing sectors. Other inputs can be regarded as information.

AREA: Input sheet

A lot of housing data is needed here, both on the present stock as well as different views on development patterns concerning types of dwellings in multi family versus single

family houses, sizes of dwellings, cooled area, individually heated hot water versus natural gas networks.
Main input: Number of households in base year or the corresponding number of person's per. household. Projection on the number of person's per. household in 2010 and 2030. Number of dwellings divided by age meaning completed before year old (1980), completed 1980-1992. If there is no characteristic difference regarding energy consumption in these two categories of dwellings all existing dwellings could be treated as one category. Dwellings in base year must be split in number of dwellings in single family houses and number of dwellings in multifamily houses.

A projection on yearly building of new dwellings in the periods 1992-2010 and 2010-2030 is needed. New dwellings are split by category using a projection on the share of single family and multifamily respectively. Base year total area must be specified both for single family and multifamily buildings. Projections on average size of new single family and multifamily dwellings are needed and can be based on the figures regarding old and medium age dwellings.

Regarding service and industry sectors total area must be specified as well as average size of buildings. This is done for all 3 years and the number of buildings are calculated from total area and area per. building.

Number of buildings by category is calculated using assumptions on number of dwelling's per. building for both base year and projection years and for the single family and multifamily type. A single family building might have more than one apartment.

Input on the distribution share of total single family and multifamily area on town size could be specified. Rural share is calculated as the residual share. The distribution shares are specified for existing (stock) and for the added area in the periods 1992-2010 and 1992-2030 respectively. The issue of town size is most important in connection with the possibility of having different degrees of connection to natural gas and heating networks in the 4 groups.

The demolition rate for existing buildings must be specified for the 3 categories and for old and new buildings. The rate is used for calculating the number of old dwellings still existing in 2010 and 2030. For service and industry the calculation is carried out directly on number of buildings.

Main output is total area split by single family and multifamily and by town size. For service and industry there is no split. Different figures are calculated to evaluate the projections made in the sheet. Most important is the number of households, which is used in other sheets. Area per. person, number of dwellings, number of buildings and total area in m2 are calculated.

HOUSES: **Input sheet**

Input data from the AREA sheet constitutes the basis for this sheet which is concerned with giving heating/cooling data based on different types of dwellings, location of dwelling combined with specific consumption data.

Input is specific consumption in GJ/m2/year of cooling or heating as well as hot water consumption in GJ per household per year. These consumption figures are applied to all area determined in the area sheet and to the total number of households. The specific consumption for heat in projection years is calculated from base year consumption and any projected saving penetration. If there is no assumed saving the specific consumption in projection years remains unchanged.

Projections on the specific consumption for hot water must be specified directly for the projection years and there is no option of saving for this use. Hot water consumption is calculated both for existing and new houses based on total area of the category of house and the average area per person for that year.

Additional calculations are carried out concerning the cost of saving of heat. The saving penetration is used and increasing marginal cost of saving is identified by the cost function and the two parameters for the cost function in columns N and O. A saving cost index of existing and new buildings respectively is used for all categories (single/multi family, industry) reflecting a decrease in saving cost in time. This calculation of extra investment is only relevant in viewing the cost of heat saving in this sheet and does not influence the other sheets in the model.

NETCOVER**: Input sheet**

The coverage of heat, cooling and natural gas network is set here.
Input: The share of total heat or cooling demand supplied by the natural gas network and heating networks must be specified for the base year and projected.

For all 3 sizes of towns the coverage percentage of the network's district heat and natural gas must be specified. The percentage of buildings connected to the networks out of those covered must be included as well. The shares are specified for both existing and new buildings and for dwellings in single family. Multi family buildings, service and industry buildings are grouped as one.

The total area covered is calculated from the shares in this sheet using the heated area grouped by town size found in the area sheet. Connected area is calculated in the same way. Rural areas are assumed to have no coverage and connection and this must be changed directly in the formula if necessary.

District heat and natural gas average connection shares are calculated. About the situation in Egypt no connection is assumed in the sheet, but it should be changed regarding natural gas networks, which have high coverage and some connection in at least the area of Cairo.

For all categories the connection shares for buildings to natural gas networks, district heating and individual heating is calculated, based on the assumptions made in this sheet. The share for the individual heating is given as the residual. In the Egyptian example all demand is met by individual heating/cooling.

The number of buildings supplied by each technology and for all categories is calculated from the shares and the number of buildings in the area sheet. No totaling of existing and new house is made in this sheet.

NET-HOUSE: **Output sheet**

This sheet calculates the heating and cooling demand measured in PJ from households and service. The demand that is not supplied by the networks is individual supply technologies. Calculations are based on the netcover and area sheets. The demand supplied by individual technologies is used as an input in the HTEC_IN sheet, which divides the demand on individual technologies and fuels. Specific consumption figures from the houses sheet is included. Calculations are made both for heating/cooling alone and for the total demand.

HTEC_IN: **Input sheet and output sheet**

Heating technologies, individual heating and cooling. Distributes the total demand of individual technologies on specified technologies characterized by fuel type.
Input: share of individual demand satisfied by specific technology/fuel type. Projections on future use of individual solar hot water collectors and use of biomass in rural areas can be specified here. Hot water from LPG or Kerosene must be included here.

The number of units of each technology is calculated, which can be used in economical calculations not carried out at present.

Fuel efficiency for each individual technology for both single family and multi family/service is included in the sheet.

Final energy demand is determined from the shares of the individual technology, the individual demand from the nethouse sheet and the fuel efficiencies.

Investment cost per unit, operation and maintenance cost as a percentage of investment and lifetime for the unit is input in this sheet, but all these input data are not used for calculations at present. Further data on emission factors regarding NOx, N2O and CH4 is included in the sheet. Emission calculations are carried out in the fen-house sheet and not here..

EL_APPL: **Input sheet**

Electric appliances used in households
Input data: Coverage percentage of households in possession of each appliance, average yearly consumption for each appliance. Projections on these two figures are needed as well.

Number of households from the area sheet constitutes the main input from outside this sheet.

It is possible to distinguish between two categories regarding energy efficiency for each type of appliance. The shares of the standard appliance and the energy efficient one is filled only for the projection years. If the share of the most efficient type is small and is anticipated to be small in the future there is no need to distinguish between the energy efficient and the non efficient type. There is a possibility to calculate cost/gains of using the most efficient type. Extra investment cost per unit for the energy efficient appliance is filled to the sheet and total extra cost for using energy efficient appliances is calculated.

There are about 17 different appliances specified but more can be added, as it is possible to reduce the number of appliances.

Output is electricity demand from households, excluding demand used for heating or hot water.

EN_SERVICE: Input sheet

Electricity demand from service sector including administration.
Demand can be specified by end use category and by 4 sectors wholesale, retail sale, public and other service sectors.

All input data regarding end use categories are filled directly including data for projection years. Total electricity demand from each of the 4 sectors is calculated as a sum of the 4 end use categories lighting, ventilation, cooling and other. For public services two more end uses is included, pumping and electronics along with a category of others.

To the 4 sectors a projection of roadlighting is added as well as a sector for others. The other sector is of course not projected on the end use level.

EN_PROC: Input sheet

Energy demand from production sectors, manufacturing, construction, agriculture and mining.
Input: Energy demand by sector and energy category in base year. For projection years production elasticity regarding both electricity and fossil fuel, price elasticity regarding electricity and fossil fuel, real growth of production in the period until 2010, 2030 respectively. For projection years the split of fossil fuel is based on input of shares for oil, coal and natural gas. These should be projected taking the actual shares of the base year into consideration.

Manufacturing sector I split based on National Account categories and not based on energy consuming industries of the country. This can be changed quite easily by changing the already existing manufacturing categories. There should be the necessary detailing of manufacturing available with 11 manufacturing industries. A possible alternative grouping could be heavy and light industry or cement, aluminum and iron processing.

For the base year actual consumption of energy by type for all sectors must be filled. The split of energy on type is used calculating the distribution of fossil fuel on oil, coal and natural gas in base year. The share of the 3 fossil fuel types must be projected. Total fossil fuel demand for projection years is calculated in an expression using production of the sector, production elasticity, price of the fossil fuel from the fuelprice sheet, price elasticity of fossil fuel demand and the base year fossil fuel demand. For electricity demand a similar calculation is carried out.

The columns with savings in PJ and total extra investment cost are not used.

In the last columns the production of the sector is filled for the base year and based on this and projected growth rates for the period 1992-2010 and 2010-2030 the production in these two years are calculated measured in real terms. For all 3 years the energy intensity is calculated as well as an indicator of the reality of the projection made. For the whole producing sector the energy intensity and growth rates are calculated as well.

FEN_PROC: **Output sheet**

Final energy demand from production sectors specified by energy source/fuel.
Input: Input are given from the En-proc sheet for the projection years, but demand in base year can be directly adjusted in this sheet. Use this possibility to make electricity demand from commodity producing sectors fit actual demand in base year.

In all 13 fuel types are included in this sheet. For 5 of these fuel types the data are filled directly in this sheet. This is done for wood, straw, biogas, solar and district heat. For the other 8 types demand in projection years are taken from the en-proc sheet. Any district heat demand from industry is distributed on town size by shares filled in this sheet.

FEN_TRAN: **Input and output sheet**

Final energy demand from transport sector.
Input: number of person transport km and freight transport ton km in base year and projections on these figures. Fuel consumption patterns for transport modes, and the fuel consumption per km.

The importance of this matter for our purpose depends on the actual electricity demand from transport and anticipated developments in this demand.

Regarding both personnel transport and freight the total is distributed on means of transport by shares for both base year and projection years. For personnel transport there are 6 categories and for freight there are 5 categories.

All categories are then distributed by shares according to their use of fuel. For all categories the sum of shares must be checked.

Load factors for the different means of transport/freight must be specified. This means the number of persons per car/plane/ferry and the tons of freight per unit transport equipment.

Specific consumption data of the transport means specified by fuel type must be included (km/l). Calorific values of the fuel are specified here as well.

Total numbers of km transport supplied by the individual transport equipment specified by fuel type is calculated. This leads to fuel consumption by vehicle type calculated in some of the first rows of this sheet. Total consumption of each fuel type is calculated by adding fuel consumption by vehicle type. These figures are situated in the top of the sheet and are the output of this sheet. Figures for 5 different fuels are calculated along with a transport demand for electricity.

FEN_HOUSE: **Output sheet**

Energy used for cooling (air-condition) and hot water are added from the individual systems and from network systems. Demand is specified by type of energy.

Total demand is given by 13 energy/fuel categories of which 10 are given from the former sheets.

Emissions are calculated for the individual supply systems and not for converted energy used for heating/cooling and hot water. Emission from the energy conversion sectors is calculated in the power sheet regarding electricity. Emission of NOx, N2O and CH4 is the only emissions described here.

FEN_APPL: **Output sheet**

Electricity demand from appliances in households and service-sector inc. lighting.
Electricity demand is calculated from the el-appl and en-service sheets. Total extra investment cost related to electricity saving measures is calculated from the same sheets.

FEN_TOTAL: **Output sheet**

Total net energy demand by category of energy. Electricity demand is one output. This is the total direct demand for energy without considering the fuel demand by energy converting sectors (electricity production).

Total demand is given by 15 types of fuel/energy added from the fen-house, fen-tran, fen-proc and fen-appl. All figures including electricity are given in PJ.

Domestic use of fuels is not calculated here as the fuel used in energy conversion is not included here. This can only be regarded as domestic direct energy demand.

FUELPRICE: **Input sheet**

Used as input in EN_PROC and POWER sheets
Input: Base year fuel prices by category. Projections on real fuel prices by 2010 and 2030. Prices must be specified as the prices paid by production sectors (industry) on average. For special fuel types used in the power production sector their price must be specified. The important fuel types are oil (mazout, solar), natural gas, coal and kerosene. If possible prices must be expressed in L.E per. GJ or per eq mazout.

At present the fuel prices are given as actual prices fall 1994 and no projections are given.

CHP_SHARE: **Input sheet**

The share of district heat demand covered by Combined Heat and Power plants. Not relevant at this time.

NETWORK: **Input sheet**

Transmission and distribution losses of the networks of natural gas, electricity and district heat.
Input: Actual electricity transmission and distribution losses as a percentage of electricity transmitted and distributed. Projections on a possible lowering of both transmission and distribution losses (% loss for the relevant years).
Output is electricity loss that is transferred to the plants and power sheets as part of total electricity demand.

PLANTS: **Input sheet**

Electricity production plants, including renewables.
Input: This sheet covers capacity development 1992-2030. There are 2 types of plant-data, on existing and planned development. All categories have these two types. Categories covers renewables, thermal plants divided by location in big cities, medium and small cities. Electricity demand is taken from the Fen-total sheet and grid losses from the Network sheet are added. This is done for the base year and the two projection years.

Electricity production capacity needed is calculated from electricity demand and interpolating between the 3 years for which demand is given.

Al existing capacity is to be specified on plant level regarding capacity, first operating year, expected life time, fuel type and fuel efficiency. Life time and plant capacity are used for calculating the still existing capacity at any time in the period 1992-2030. Fuel type and fuel efficiency are not used at this level, but some average efficiency has to be specified in the power sheet. Fuel types are not used at present, but could be used for determining the relevant fuel price to use in the calculations in the power sheet.

Planned capacity expansion for thermal plant is to be specified on which technology used, planned operation start, lifetime, fuel and fuel efficiency.

For each year in the period 1992-2030 the available capacity is calculated and must be compared to the necessary demand capacity. Demand capacity is based on total electricity demand from former sheets incl. transmission losses adjusted from demand flow to demand for capacity by a capacity load factor set at 5000 hours a year.

Aggregated capacity figures are transmitted to the power sheet.

All Egyptian plants are placed in the group of big power plants.
The rows describing power plants in medium and minor towns are not used at present.

Statistic of capacity, development plans and actual production of renewables is available at NREA. These data will soon be introduced in the plants sheet. Other sources than wind energy should be considered, no matter they are not economically competitive at the moment. Wind development can be specified year by year and specific known expansion programs or specific windfarms can be specified. Regarding wind the capacity value of wind power is less than thermal plants, which means a correction factor (wind capacity value) must be applied. This factor works through both plants and power sheets. A capacity value regarding photovoltaic must be specified as well. The capacity value is the same for the whole period but it should be changed if there is a big change in the share of wind or photovoltaic capacity.

Electricity statistics on the traditional plants are already in the sheet but they must be verified specially concerning the production start time and the estimated total lifetime of the plant. Further data on fuel efficiency of specific plants are needed as well as the actual production of each plant for 1992. Data on this issue can be found in the yearly EEA publication. Main fuel input type has to be specified as well. If available efficiency estimates for the scenario years 2010 and 2030 should be added to the sheet.
The working groups could point to expected relevant technologies in the scenario years. Is any of the future technologies specified in the plant sheet incorporated in existing plans for electric supply development ?

Traditional power plant development will have to be specified in detail on plant type or as a total construction of thermal plant in future years. In the long run there will probably only be expectations available.
Output is total production capacity from existing and planned capacity in every year from 1992 till 2030. This can be seen as a death curve for capacity.

Renewables are treated in the following way in the plants sheet. Categories are wind power, photovoltaic and hydro power.

Wind power: This category is the most detailed and has specifications on specific planned wind-farms, with known completion year, and development plans on yearly wind capacity expansion. More expansion programs can be included. Anticipated yearly development of small scale stand alone wt's can be specified.

Wind capacity value: All wind capacity figures are measured as installed capacity but total renewables include a correction of wind capacity corresponding to the availability of wind capacity. The correction factor (wind capacity value) is 35% at present but is changeable.

Hydro power includes small scale hydro as well as the big dams. A life time of 50 years for hydro power is assumed, and the existing hydro power is assumed replaced at the end of life time.

Input data: Wind: input for development covers two types.
a) Specified by installation year, capacity and lifetime for wt's in general and for each wind farm.
b) Specified by start year, yearly expansion of capacity and period of the expansion program.

Wind capacity share is calculated adjusted by wind capacity value. This is the share of existing and planned capacity, not securing that supply meet's demand as is done in the power sheet. Another wind capacity share of total capacity including extra expansion can be found in the power sheet. Wind capacity shares and wind expansion in MW can be viewed as graphs.

POWER: **Input and output sheet**

Aggregated match of electricity demand and supply including fuel consumption, production cost and emissions.

This sheet covers aggregated electricity supply and long run scenario adjustments to total electricity capacity (extra capacity development). The sheet only operates 3 years: base year, mid-year and end-year. Electricity production, fuel demand, fuel cost, levelized production cost and emissions are determined for each category.

There are 3 types of plant-data, on existing, planned and required extra production capacity. Existing and planned capacities are taken from the plants sheet.

Input: Concerning economical figures' estimates of present investment cost in Egypt by plant type as well as the corresponding maintenance cost is wanted. Figures could be million L.E per. MW installed capacity, and maintenance in percentage of investment cost. Estimates for coal fired conventional plant, combined cycle natural gas fired plant and renewables (wind) must be stated. If possible judgments on future development in costs can be specified. Cost may change due to growing Egyptian produced share of the plant or windturbines.
Regarding projection of economical figures all projected figures must be specified in real terms. Emissions' coefficients regarding NOx and SO2 are specified to calculate total emissions. CO2 emissions are not calculated here. Production hours per. year measured at full load must be projected for each group of production plants.

Wind power issues.
Wind capacity is total existing and total planned capacity from the plants sheet measured as installed capacity. Total renewables is adjusted by the wind capacity value from the plants sheet. Extra wind capacity can be added if wanted.

Adjusted wind capacity share is obtainable as a graph along with total renewables share, and this figure does include any extra capacity from the power sheet. Regarding total adjusted capacity share only 3 years are obtainable.

Output: This sheet must be viewed as the main output sheet for our purpose. Output could be the wind share of total electricity production capacity, production cost by wind power, saved fuel due to the use of wind in power production and reduced emissions of the power sector due to wind and other renewables production.
For all categories of power production plants total capacity, electricity production cost pr kWh, fuel consumption and emissions are calculated.

Electricity production is calculated for each category. The average full load hours pr. year specified for each category in this sheet is used for the calculation. Average hours must be specified in the base year to fit actual production, but for the projection years the expected availability of production capacity must be specified adjusted by any planned reserve capacity. Reserve capacity can be distributed on the different categories or referred to the oldest plants. Wind is treated at expected average full load hours per. year. Hours are connected to the total capacity for each category including the extra capacity introduced in the power sheet. Total electricity production must be compared to total demand to ensure that the necessary production is available. The share of production for renewables and wind is calculated and illustrated in graphs. Graphs for distribution of electricity production on production category are available as pie graphs for all 3 years.

The fuel used for electricity production is calculated for the categories in the power sheet based on electricity production and fuel efficiencies from the power sheet. The calculation is not based on fuel efficiencies and electricity production from the plants sheet. Concerning renewables the corresponding amount of fuel saved is calculated based on the assumption that renewable production substitutes new existing capacity in the base year and natural gas combined cycle capacity in projection years. Saved fuel by wind and total renewables is illustrated in a build in graph. All fuel consumption figures are calculated in PJ and not distributed on fuel categories.

Emissions are calculated from fuel consumption and the relevant emission's factors for NOx and SO2. Regarding CO2 emissions are not calculated in this sheet as only the NOx and SO2 emissions are connected to the actual plant category and not only the fuel as for CO2. The reduced emissions due to use of renewables are not calculated but they could be calculated from the saved fuel and emission factors for new existing plants and natural gas combined plants respectively.

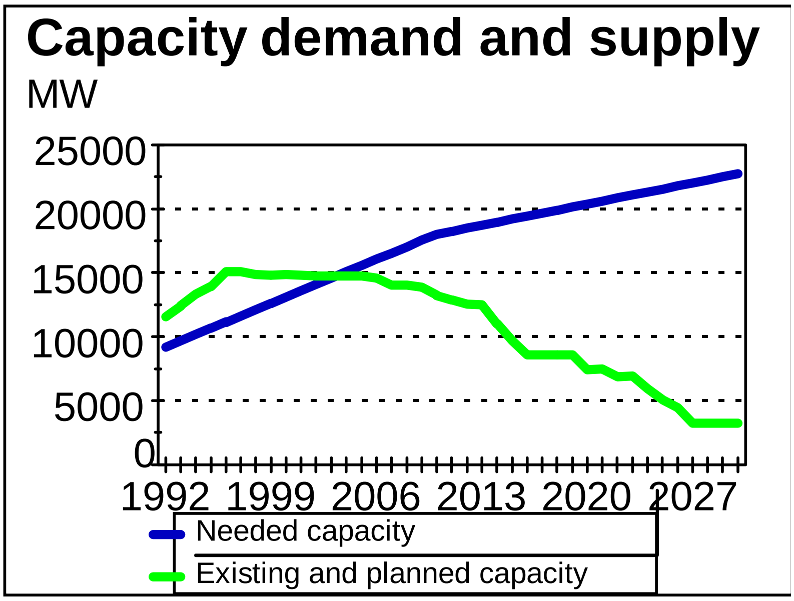
Cost of electricity production is calculated for fuel used pr kWh produced by plant category and for total electricity production. A measure of total cost including a levelized investment cost is calculated as well. Fuel prices per. GJ fuel are taken from the fuelprice sheet. Actual fuel category is only characterized by the text in the categories in the rows. Regarding existing capacity fuel for new plants are assumed to be natural gas and for medium age and old plants the fuel used is fuel oil, which in the Egypt case is heavy fuel (mazout). Renewables has no fuel cost.

Investment cost for plants measured per kW capacity is specified along with operating cost as a percentage of investment cost. Considering the life time for the plant, actual capacity of the plant category and the real discount rate in the society sheet a levelized investment cost is calculated. A measure for total cost per produced kWh in each year is calculated based on levelized cost, operation and maintenance cost and fuel cost. This is based on the investment cost in the actual year and not the cost of the stock of capacity. Fuel cost is the fuel cost in the actual year and not a full specification of fuel price developments in the lifetime of the plant. This means the measure calculated here is not suitable for comparing investment opportunities, nor for calculating exact cost of using the actual production capacity.

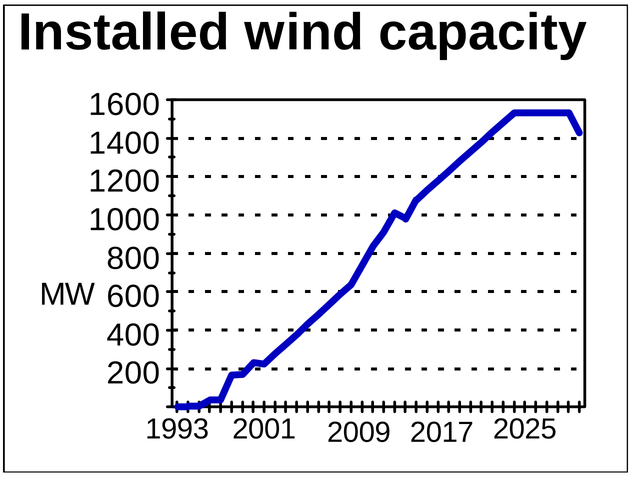
The cost measure does give some idea of the cost of renewable production compared to different traditional production technologies. Fuel price development assumptions can be evaluated regarding the consequences for the competitiveness of renewable production including wind. The electricity production cost of the total capacity can be examined and the total cost influence from introducing renewable production can be evaluated.

Some output examples from the power sheet are illustrated below.

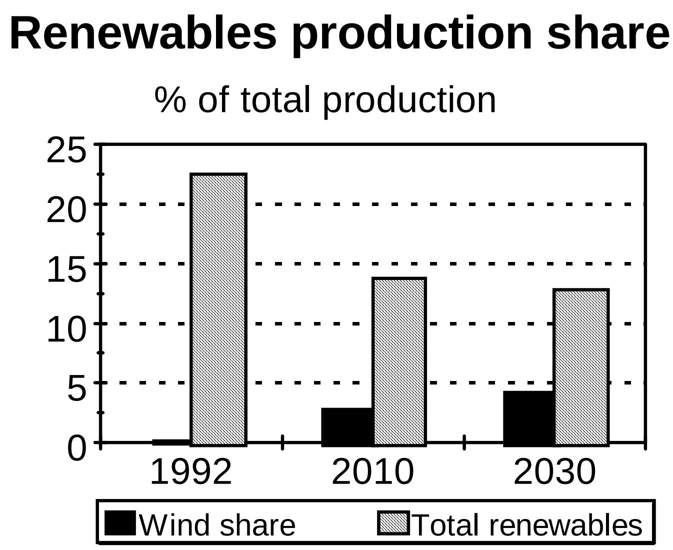
The demand for capacity and the match of existing capacity and planned capacity in the plants sheet can be viewed in the following graph. This gives an indication of the need for extra capacity or the need to change planning in the plants sheet.



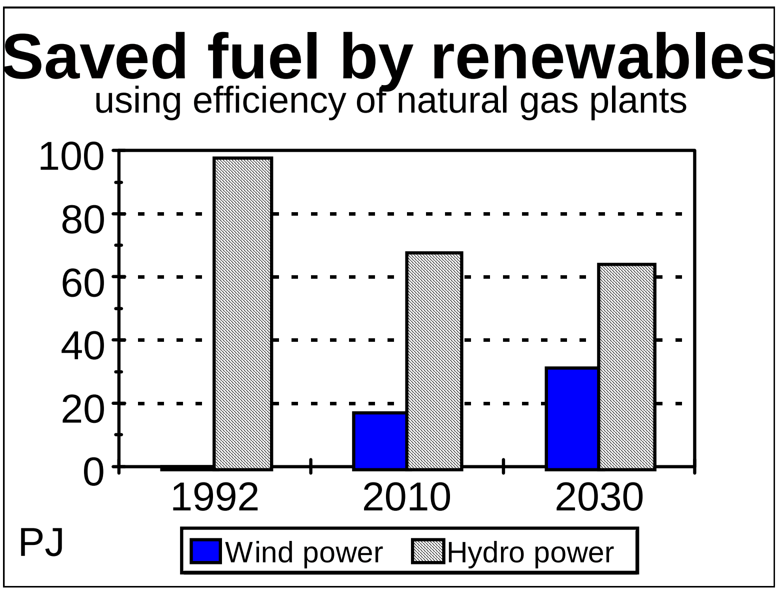
Wind capacity development from the plants sheet is illustrated below unadjusted for capacity value.



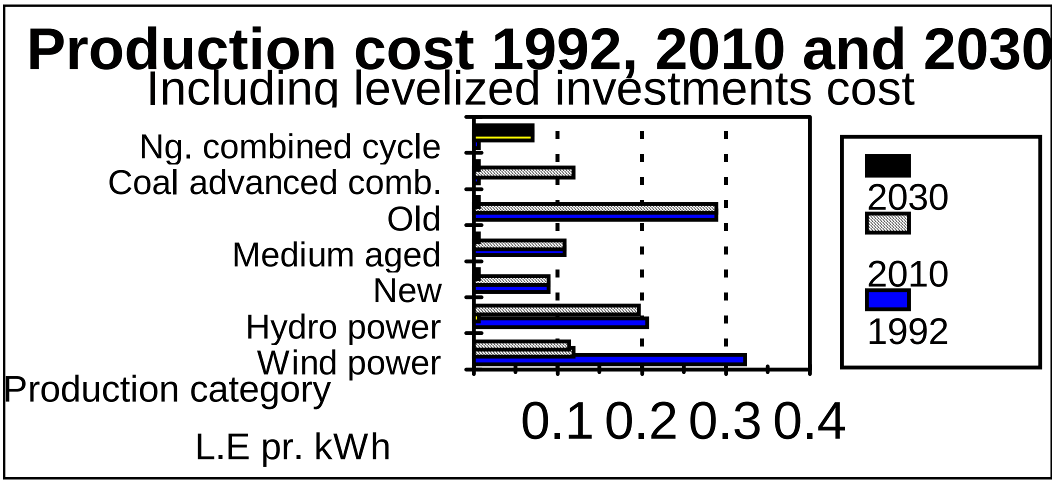
Production share for renewables below does include hydro power and is based on a growing total demand.



Fuel saving as a result of the use of renewables and wind in the previous figures is shown in another graph.



The figure below is based on Egyptian figures regarding fuel prices but fuel efficiencies, investment cost and operation and maintenance cost have not been verified.



The plants and power sheet could evaluate specific development plans on wind power regarding the above mentioned issues.

General view on input and output sheets

In all the sheets input cells are white and accessible, while calculated cells are yellow and non accessible. It's not all white cells that have to be filled to make the model run.

Calculations are carried out by using the F9 button. Links from sheet to sheet are numerous, but the most important are shown in the model diagram.

Main output sheets are Fen-house, Fen-appl, Fen-service, Fen-proc and Fen-total concerning demand for all energy categories. For electricity supply the output sheet is Power.

All ready made graphs can be viewed and edited both from the graph menu and from the last page of the workbook, the graph page, which include 13 graphs at present. Access to the graph page is through the small arrow in the white box at the bottom line.

Some documentation including the diagram of the model is to be found in the help facility of the model as well as in this documentation.

Please note the model is not a fancy program including user-interface, specified output-forms and user-manual. This is meant as a tool that should be developed further to suit the actual needs. For this reason there has been use of rather simple functions in a spreadsheet system which should be able to change for an experienced user of the Quattro Pro.
The system of 20 sheets is of a size and the number of assumptions so many that a through knowledge of the sheets can only be achieved by some month concentrated use. An introduction of some 1 week should make a user capable of changing a few main assumptions and filling specific data to the sheets. Tracking calculations through the sheets for changing specific values requires some knowledge of Quattro Pro and takes time.

Running the supply system on an isolated basis

The sheets of plants and power can be used isolated from the rest of the system if the only aim is to describe the electricity production system. Just do not pay attention to the needed capacity and total electricity demand.

Alternatively a projection of electricity demand from another source can be used as input in the plants and power sheets. Just unprotect and fill in the AX-AZ cells of the plants sheet. Still data from other sources are needed including the Set, Society and Fuelprice sheets.

Operating scenarios in the BRUSII-model

Scenarios are made by changing data in input cells, recalculating, and examining output figures. Every scenario has to be saved as a new workbook-file if it to be kept. Output results can only be compared as prints of relevant sheets or specific graphs. There are no facilities for comparing scenarios. A scenario should only consist of changes in cells and projection years 2010 and 2030. Base year assumptions should not be changed.
In general a scenario includes a lot of assumptions that are somehow connected in the direction they move the whole system. This could be a green society focusing on a lot of measures for reducing demand for all kinds of energy and a great share of green conversion technologies in electricity production. Another total scenario could be a fast growth in all determinants of energy demand, no focus on energy conservation measures, and expansion of electricity production only based on minimizing direct economical costs. Partial scenarios or could be made as well on specific issues of interest, calculating consequences of certain actions or changed assumptions.

Examples of scenarios on demand.

GDP growth
To produce demand scenarios on GDP growth projections the relevant input sheet is en-proc. Only commodities sectors demand for energy responds to GDP growth. Total GDP growth is shown in this sheet but no demand figures respond to GDP directly. All growth rates of manufacturing sectors, agriculture and construction can be changed in this sheet and energy demand from each sector responds to the change of their own growth rate of production. Growth rates of sectors are changed in the last two columns of the sheet row 2 for each sector. Total commodities sector could be set to grow in line with GDP or maybe a little slower. Output results could be analyzed as the effect on total net energy demand by category in the fen-total sheet or the influence on electricity supply system could be investigated on the robustness of a capacity expansion program. Other GDP growth rates could be examined on the question of the room left for expansion of the wind energy capacity.

Population growth.
Population is set in the society sheet and effect demand of heating and hot water for households. Electricity demand is affected by use of electric appliances in households as well. Both effects go through the area sheet determining the numbers of households.
Output results will be seen in the fen-total sheet on demand for electricity and demand for fuel types for heating and hot water. The share of the change of demand for hot water going through to electricity demand depends on a lot of parameters in the sheets

of houses, netcover and htec-in. Regarding effect on supply system the above mentioned effects can be examined in this case as well.

Examples of electricity capacity scenarios of which some have been carried out during the work on introducing NREA to the model.

Wind expansion programs.
In the plants sheet there are a number of rows for wind development. If a program includes specific development plans of for instance 60 MW at Zafarana 1998 these figures can be entered in the 3 columns following the last yellow column of the years from 1992 till 2030. Capacity of the windfarm, commissioning year and lifetime must be entered. If the plan includes a development of 20 MW every year from 1998 till 2015 this can be entered below the specific windfarms. The yearly expansion of capacity, first expansion year and the expansion number of years must be specified.
Output is total wind capacity from this plan every year from 1992 till 2030. The share of wind capacity of total planned and existing capacity can be examined along with saved fuel electricity production from wind, the share of electricity produced by wind and the production cost of both the wind and the total electricity system. Cost responds to gross production and not to enduse of electricity. The wind development plan could be compared to the match of total needed capacity to planned total capacity.

Wind production parameters.
Wind production measured as full load production hours could be changed due to experiences or as a result of changes in the planned location of windfarms. Improvements in technology as well as changing dimensions could be another reason for changing this parameter.

Windturbines in remote areas.
One scenario could be changing the focus from big windfarms to a widespread use of small scale windturbines in remote areas. Is the potential of these areas of a size that allows reaching the target of 5% renewables in energy end use by the year 2005 ?. This means development of wind must be only settled contracts for windfarms and a yearly development plan for small scale unconnected wt's.

Investment cost for wt's
A very interesting scenario could be the competitive position of wind energy if a very high degree of producing the windturbines in Egypt could be achieved. In the power sheet the relevant figures for investment cost should be changed for this calculation.

Solar cells.
Solar cell's development programs could be analyzed in the plants sheet in line with development programs for wind energy. The base case for this renewable group has not been filled yet. Issues of production capabilities in Egypt of the technology and results of anticipated falling investment costs could be examined.

Energy and fuel prices.
This scenario could be on a fast growth of real fuel prices making wind and solar cells much more competitive in future years, thus leaving a fast development of wind energy a possibility in the future. Energy prices are easily changed in the fuelprice sheet. On

the demand side there could be an effect of raising electricity prices, which can be done in the fuelprice sheet as well.

Total renewables scenarios

Scenarios including both wind, solar cells (photovoltaic), biomass and solar hot water could be constructed. This requires many data that might be difficult to acquire and includes a levelizing of other energy demands in base year that has not been done yet.

More complex scenarios could be constructed as a combination of some of the above suggested scenarios/calculations.